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# FEMTOSECOND LASER PULSE DIAGNOSTICS

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## I. INTRODUCTION

In the Laser Branch of the Armstrong Laboratory (AL/OEDL), we routinely generate pulses over the range of 5 nanoseconds (ns) down to 50 femtoseconds (fs) and utilize these pulses in many different types of experiments. Because single pulses are required in most of our experiments, it became necessary to measure the individual pulsewidths instead of utilizing our standard slow-scan autocorrelator, which averages hundreds of pulses over tens of seconds to obtain the full-width-half-maximum (FWHM) of the average. A need to know the pulse-to-pulse variations in our research efforts was paramount since the standard slow-scan

autocorrelator method could not measure anything other than the average [1]. We based our design on a single-shot autocorrelator using a background-free Michelson interferometer to measure the time behavior of single pulses from our lasers [2,3,4].

## II. AUTOCORRELATOR

### A. Autocorrelator Set-up

A single-shot autocorrelator is based on a spatio-temporal transformation that measures a spatial profile proportional to the second-order autocorrelation function of the incident pulse. We record the spatial profile of the second-harmonic signal which contains the equivalent information as measured by a classical autocorrelator and calculate the fundamental pulsewidth utilizing a calibration factor and a form factor. A beam diagnostic instrument (Beamgrabber, Model 6100) records the image and performs the calculations. The optical layout of the autocorrelator is shown in Fig. 1.

As shown in the Fig. 1, a noncollinear beam arrangement is used to obtain a background-free signal, and the two beams cross in a KDP crystal. The angle between the two beams has been reduced to a minimum because the frequency-doubling mechanism in the KDP crystal is nearly the same for the bisector as for the two incident beams when the angle is very small. Thus, three light beams are produced at the second harmonic frequency; each propagating in different directions. Only the beam produced in the bisector contains the autocorrelation information and requires that both beams overlap inside the crystal in space and time.

In a classical slow-scan autocorrelator, the two beams are usually focused on the nonlinear crystal, and the second-harmonic signal is recorded only at the bisector since spatial information is not required. In the single-shot autocorrelator, the beams are defocused and spread out over the entire surface area of the nonlinear crystal to produce the spatially generated second harmonic signal. The shape of the spatially generated second harmonic contains information relative to the temporal

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profile of the original pulse. A charge-coupled device (CCD camera, Cohu Model 4800) records the spatial image by integrating the time history of the second harmonic generated in the KDP crystal.

### B. Design

This autocorrelator was designed to operate with wavelengths between 532 and 580 nm and for pulsewidths as short as 50 fs. The KDP crystal was fabricated to our specifications of 30 mm in diameter, 300 micrometers ( $\mu\text{m}$ ) in thickness, and cut with an angle between 68 and 82 deg. The actual usable diameter is 28 mm, and the KDP crystal is mounted with a 1-mm-thick sapphire window in front and an ultraviolet filter (Schott Glass, UG-11) behind to block the fundamental. As shown in Fig. 1, a 50-mm focal length lens focuses the three beams on the CCD detector in the camera. The camera is the detector of the Beamgrabber laser diagnostic instrument and presents a full two-dimensional image of the three beams on the CRT screen. However, only the horizontal profile contains the autocorrelation information, which is in the plane of the three second harmonic beams propagating from the surface of the KDP crystal. This instrument captures and analyzes the images recorded from a single pulse and presents the data as the width in micrometers of the half-intensity points from the autocorrelation signal. This width is then multiplied by the calibration factor and the form factor to obtain the FWHM pulsewidth.

### C. Calibration

The calibration on this instrument is carried out in exactly the same procedure as the classical autocorrelator by

introducing a known calibrated delay in one beam path and recording the translation of the second harmonic image on the camera [4]. The Beamgrabber performs all calculations for this calibration.

## III. RESULTS

This single-shot autocorrelator measures individual pulsewidths from laser in the visible wavelengths between 532 and 580 nm and has a calibration factor of 400  $\mu\text{m}$  of translation for a 317-fs delay in one beam. A form factor of 1.414 is used in the calculations for an assumed  $\text{TEM}_{00}$  pulse profile.

### ACKNOWLEDGMENT

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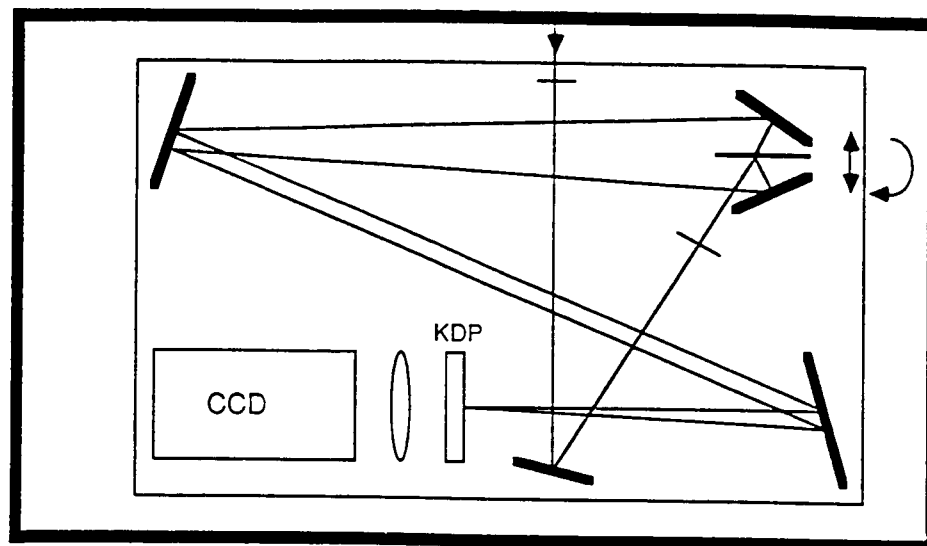


Fig. 1. Single-shot autocorrelator optical layout.